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Artículo de Revisión

SMALL MAMMALS IN URBAN AREAS IN BRAZIL, A SYSTEMATIC REVIEW

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ABSTRACT. This paper seeks to catalog the terrestrial small mammal diversity, their distribution in sub(urban) environments of Brazil using a systematic review performed on five literature indexing databases (LILACS, Scopus, PubMed, SciELO, and Web of Science). Sixty-eight articles met the predefined inclusion criteria. Fifty-one terrestrial small mammal taxa were retrieved, with 22 marsupials and 29 rodents. Twenty-eight taxa (17 rodents, 11 marsupials) were exclusively found in forest fragments, 15 (10 rodents, five marsupials) exclusively found in urban areas, and eight (three rodents, five marsupials) in both environments. The study encompassed research conducted in 14 of 27 federative units, with studies concentrated in Minas Gerais and São Paulo, while Espirito Santo reported a single species. The majority of the studies were focused on zoonoses, with only one inventory survey. Most studies were clustered between 2017 and 2021, with only four conducted before 1990. The disparity in research distribution was anticipated, given the concentration of research institutions and researchers. Our findings underscore the pivotal role of urban forest remnants in maintaining biodiversity within urban landscapes and the need for more comprehensive, geographically balanced research efforts, especially in the understudied regions, to enrich our understanding of terrestrial small mammal diversity in Brazil.

RESUMO. PEQUENOS MAMÍFEROS EM ÁREAS URBANAS DO BRASIL, UMA REVISÃO SISTEMÁTICA. O presente estudo busca catalogar a diversidade de pequenos mamíferos terrestres, sua distribuição em ambientes (sub)urbanos no Brasil usando uma revisão sistemática realizada em cinco bases de indexação de literatura (LILACS, Scopus, PubMed, SciELO, e Web of Science). Sessenta e seis artigos cumpriram os critérios de inclusão pré-definidos. Cinquenta e cinco táxons de pequenos mamíferos foram encontrados, sendo 22 marsupiais e 29 roedores. Vinte e oito táxons (17 roedores e 11 marsupiais) foram exclusivos de fragmentos florestais, 15 (10 roedores, cinco marsupiais) em áreas urbanas, e oito (três roedores, cinco marsupiais) em ambos. O estudo incluiu trabalhos conduzidos em 14 das 27 unidades federativas, com concentração em Minas Gerais e São Paulo, enquanto uma única espécie foi reportada no Espirito Santo. A maioria dos estudos focou em zoonoses, com apenas um inventário de espécies. Os estudos foram concentrados entre 2017 e 2021, com apenas quatro estudos antes de 1990. A disparidade da distribuição dos estudos era esperada, dada a concentração de pesquisadores e instituições de pesquisa. Os achados presentes explicitam o papel pivotal dos fragmentos florestais urbanos em manter biodiversidade em paisagens urbanas, e a necessidade de esforços de investigação mais abrangentes e bem-distribuidos geografiamente, especialmente em regiões pouco estudadas, para enriquecer a compreensão da diversidade de pequenos mamíferos no Brasil.

Key words: Rodents, Marsupials, Species diversity, urban/sub-urban environments.

Palavras-chaves: Roedores, Marsupiais, diversidade de espécies, ambientes urbanos/sub-urbanos.

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INTRODUCTION

Urbanization stands as one of the main processes driving ecosystem and landscape change, with the expansion of the urban environment substituting and fragmenting native ecosystems (Ompad et al. 2007; Grimm et al. 2008). The ecological changes caused by urbanization represent a homogenizing force on biodiversity (McKinney 2006), with the general tendency of removing specialized and sensitive species while promoting the dominance of resilient generalists and the introduction of alien species, although with varied responses among taxa (Grimm et al. 2008; Faeth et al. 2011). The resulting communities tend to be subsets of the original diversity, dominated by species highly adapted to urban environments (McKinney 2002).

The expansion, impact, and ubiquity of urban sprawl as an ecosystem highlights the urgent necessity of understanding the relationship between urbanization and biodiversity (Faeth et al. 2011). This is essential for the conservation of biodiversity and protection of ecosystem function (Grimm et al. 2008; Soanes et al. 2023), as well as impacting (directly and indirectly) ecosystem services and urban quality of life (Bai et al. 2017) and disease emergence and transmission (Hassell et al. 2017).

Brazil occupies a unique position of being both the most biodiverse country and experiencing one of the highest rates of urbanization (Seto et al. 2013; Abranches 2020). Notably, a significant portion of the urban expansion is taking place within the Atlantic Forest biodiversity hot spot (Lembi et al. 2020). However, the field of urban ecology is in its infancy in the country, with disproportionate attention dedicated to studies on botany and social aspects (Sartori et al. 2023). While birds and invertebrates have received significant attention (Pacheco & Vasconcelos 2007; Rodrigues et al. 2018; Valente-Gaiesky 2019; Alexandrino et al. 2022; Sartori et al. 2023), other taxa and general faunal surveys remain understudied.

To address the gap on adequate studies on mammal urban diversity, the present study aims to compile the known records of terrestrial small mammals (rodents and marsupials) in urban environments in Brazil using systematic review tools. Our objectives are: 1) create a catalog of the diversity of terrestrial small mammals occurring in urban areas; 2) map the distribution of studies and records; and 3) understand the contribution of different scientific subjects to the knowledge of small mammal diversity in urban settings.

MATERIALS AND METHODS

Systematic search protocol

In September 2023, we performed systematic searches in five literature indexing bases: LILACS (Latin American and Caribbean Health Science Literature, https://lilacs.bvsalud.org/en/), Scopus (https://www.scopus.com), PubMed (https://pubmed.ncbi.nlm.nih.gov), SciELO (Scientific Electronic Library Online, https://scielo.org/pt), and Web of Science (accessed through Periódicos CAPES, https://www-webofscience.ez10.periodicos.capes.gov.br/wos/woscc/basic-search). We designed keyword strings relating to terrestrial small mammals, the urban and/or synanthropic habit/environment, and restricting the search to Brazil in international bases, adapted to each base's search syntax (**Table** 1). The search was conducted without language or timespan restriction. We chose not to include terms regarding invasive synanthropic rats (*Rattus* and *Mus*) due to the large amount of bycatch papers given their significance for other fields of study (e.g., as model animals for experimental studies), and given their ubiquity and worldwide distribution associated with human occupation (Feng & Himsworth 2013), they can reasonably be assumed present in any urban center and be considered covered by the terms relative to rodents.

Processing search results

The results of the searches were imported to reference manager software. Duplicate removal was performed in two stages: 1) automatic duplicate removal using the reference manager's library management toolset; 2) manual removal by comparing author list, title, year, journal, and DOI. The second step was made necessary due to discrepancies on formatting and indexing of information (e.g., journal name in full *versus* abbreviated), as well as issues with the author indexing (e.g., duplicates not detected due to the surname of the first author being indexed as "da Silva" in one base and "Silva" in the other, first author with two surnames hyphenated *versus* a single surname), and language discrepancies (i.e., one base indexing the manuscript with the title in Portuguese, while others indexing it with the title translated into English).

A stepwise triage of the retrieved studies was performed according to the following exclusion criteria: 1) removing gray literature; 2) studies performed outside of Brazil; 3) studies with no clear presence of rodents and/or other terrestrial small mammals; 4) studies conducted in non-(sub)urban environment (e.g., rural environment); 5) exclusion of reviews and studies without original data gathering. Studies including *Rattus* and *Mus* as the only rodent species were excluded in accordance with criteria 3). The stepwise triage was performed reading the title and abstract. The remaining studies had the full text obtained to check: i) whether the study effectively attended the criteria; ii) species recorded; iii) type of environment as reported by the authors; iv) geographical location of the study; v) methods used for sampling; vi) type of study. Data extracted was organized in spreadsheets and presented in descriptive statistics. Taxonomy was updated according to GBIF (www.gbif.org)

Two researchers performed the stepwise triage of the entries independently, with comparison of the articles classified in each exclusion category. The development of

Table 1

Systematic search strategy, presented as formatted for each database.

Base searched	Search string
LILACS	((Urban OR Synanthropic OR Synurban OR suburban)) AND ((rodent OR "small mammal.ᴼR Didelphi*)) AND ((Brazil OR Brasil))
SciELO	(Urban OR Synanthropic OR Synurban OR suburban) AND (rodent OR "small mammal.ᴼR Didelphi*)
Web of Science	(Urban OR Synanthropic OR Synurban OR suburban)(Topic) AND (rodent OR "small mammal.ᴼR Didelphi*)(topic) AND (Brazil OR Brasil)(All Fields)
Scopus	TITLE-ABS-KEY-AUTH (urban OR synanthropic OR synurban OR suburban) AND TITLE-ABS-KEY-AUTH (rodent OR "small mammal.ᴼR Didelphi*) AND TITLE-ABS-KEY (brazil OR brasil)
PubMed	(Urban OR Synanthropic OR Synurban OR suburban) AND (rodent OR "small mammal.ᴼR Didelphi*) AND (Brasil OR Brazil)

the search protocol and triage was based on the recommendations of the PRISMA protocol (Page et al. 2021).

Taxonomy and distribution check

The species names and localities of occurrence recovered from the literature were checked and compared to the Species Catalogue of the Brazilian Society of Mammalogy (SBMz) (Abreu et al. 2022). Nomenclature issues detected by discrepancies between the locality recovered from literature and the information obtained from the SBMz catalogue were addressed according to recent literature and/or taxonomical advice provided by experts, including Percequillo et al. (2008), Bonvicino et al. (2014), Patton et al. (2015), Voss et al. (2018), Voss et al. (2019), Dalapicolla et al. (2024).

RESULTS

A total of 617 unique studies were retrieved by our systematic search. Eighty-six manuscripts qualified for the full-text stage screening, of which 68 were finally included in the study (**Fig**. 1).

Fifty-one species were retrieved from the studies (**Table S1**), including 11 instances of identification to the level of genus and one subspecies. Marsupials were represented by 22 taxa, including five identifications to the level of genus (*Didelphis*, *Cryptonanus*, *Caluromys*, *Metachirus*, *Micoreus*) and one subspecies (*Gracilinanus agilis agilis*). Rodents were represented by 29 taxa from six families: Caviidae (one sp.), Ctenomyidae (one sp.), Dasyproctidae (one sp.), Echimidae (three sp., including one identification to the level of genus with *Trinomys*), Sciuridae (one sp.), and Cricetidae (Sigmodontinae, 22 sp., including five identifications to the level of genus with *Akodon*, *Cerradomys*, *Calomys*, *Euryoryzomys*, and *Oecomys*).

Twenty-six taxa (15 rodents and 11 marsupials, including four identified to genus) were exclusively found in forest fragments, while 15 (10 rodents and five marsupials, including five identified to genus and one subspecies) were exclusive to urban areas, and eight species (three rodents and five marsupials) were recorded in both environments (**Fig**. 2). Overall, forest fragments contributed with 62 % of the rodent and 72.7 % of the marsupial species richness, while urban environments contributed with 44.8 % of the rodent and 45.4 % of marsupial richness recorded.

Studies were conducted in 14 of the 27 federative units of Brazil (**Table** 2; **Fig**. 3). Minas Gerais and São Paulo are tied for the states with the most studies (15), followed by Rio de Janeiro, Paraná, and Mato Grosso do Sul (6), and Amazonas (4). São Paulo was the state with the most localities (municipalities) sampled (24), followed by Minas Gerais and Pernambuco (4), and Rio de Janeiro, Paraná, and Rio Grande do Sul (3). Regarding the regional division of Brazil, the southeastern region was represented by all 4 states and 37 studies that sampled 32 localities, followed by the northeastern region with 5 out of 9 states represented (9 studies in 10 localities), the southern region had 2 out of 3 states (with 9 studies in 6 localities), the midwestern region had one out of four states (with six studies in one locality), and the northern region had two out of seven states (with seven studies in two localities). Seventeen species (seven rodents and 10 marsupials) were found in more than one locality. Minas Gerais was the state with the highest richness observed (18 taxa, including four identified to genus, 12 rodents, and six marsupials), followed by São Paulo (16 taxa, including one identified to genus, seven rodents, and nine marsupials), Pernambuco (14 taxa, seven rodents, and seven marsupials), and Rio de Janeiro (10 taxa, four rodents, and six marsupials). One state had a single species recorded: Espirito Santo (*Guerlinguetus brasiliensis*). Bahia presented

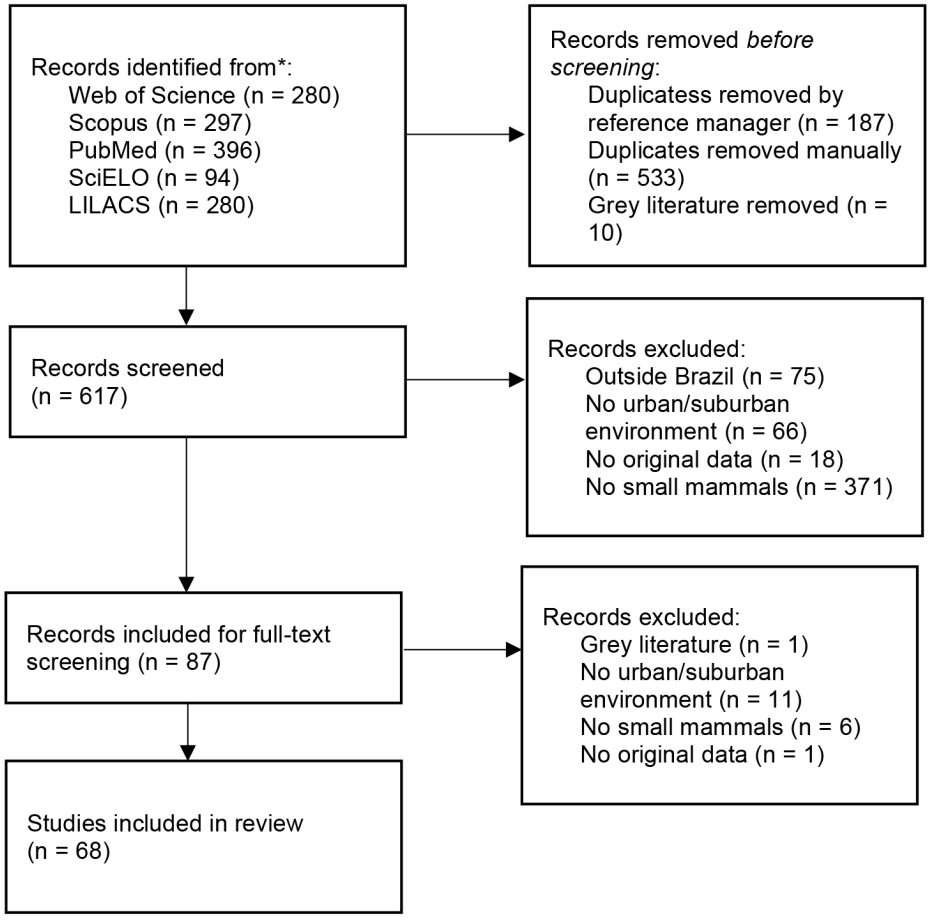
Records identified from*:
Web of Science (n = 280)
Scopus (n = 297)
PubMed (n = 396)
SciELO (n = 94)
LILACS (n = 280)
Records removed *before screening*:
Duplicatess removed by reference manager (n = 187)
Duplicates removed manually (n = 533)
Grey literature removed (n = 10)
Records screened (n = 617)
Records excluded:
Outside Brazil (n = 75)
No urban/suburban environment (n = 66)
No original data (n = 18)
No small mammals (n = 371)
Records included for full-text screening (n = 87)
Records excluded:
Grey literature (n = 1)
No urban/suburban environment (n = 11)
No small mammals (n = 6)
No original data (n = 1)
Studies included in review (n = 68)

Fig. 1. Flowchart of the systematic search and triage process.

five taxa, but four were identified only to the level of genus. *Didelphis albiventris* was present in the most records (36), followed by *Didelphis aurita* (18), *Didelphis marsupialis* (11) and *Necromys lasiurus* (6).

Studies on zoonosis were the most common type of study found (51), with 19 rodents and 16 marsupials recorded. Studies on ecology (14) recorded nine rodents and 12 marsupials (**Fig**. 5). The only study on genetics found focused on *Didelphis albiventris*, and the only inventory survey found recorded 6 rodents and five marsupials. Overall, zoonosis studies contributed with 65.5 % of rodent and 69.5 % of marsupial richness, ecology studies contributed with 31 % of rodent and 52.1 % of marsupial richness, and inventory studies contributed with 18.7 % of rodent and 21.7 % of the marsupial richness recorded.

Most studies conducted in urban settings are concentrated in the period between 2017 and 2021 (**Fig**. 4). Only four studies were conducted before 1990 (one in the 1970s performed in Pará, three in the 1980s performed in Amazonas, Piauí, and Minas Gerais), and two major gaps in publications are noticeable, one between 1994 and 2001 and the other between 2003 and 2007. All publications before the year 2000 were exclusively focused on zoonosis-related studies.

All taxa (after nomenclature corrections performed based on the information provided by experts and/or literature) were found within their expected distribution, except for *Oligoryzomys matogrossae*, recorded in the state of Maranhão, which has no records for the genus. 20 taxa were corrected to the adequate nomenclature after literature and expert

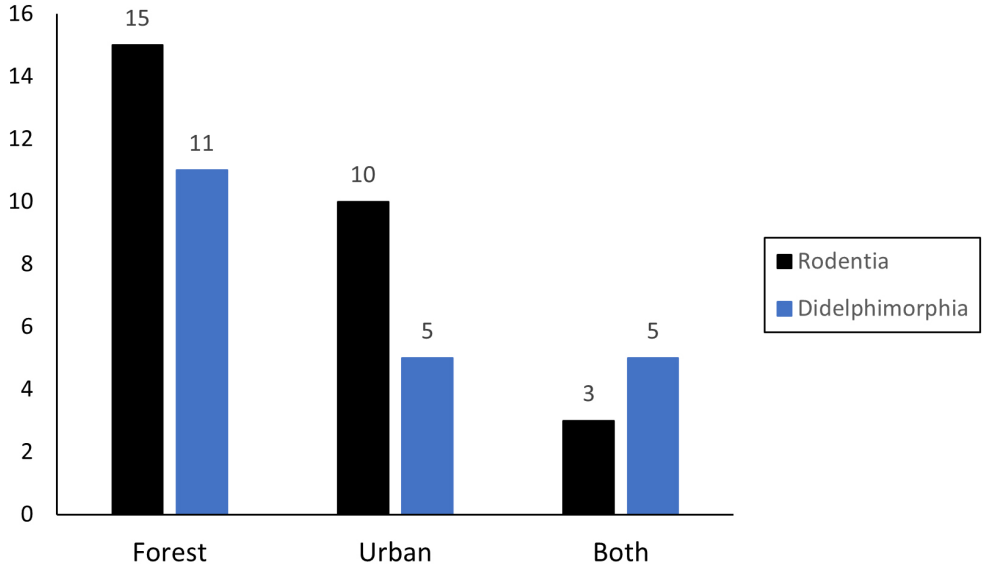

Fig. 2. Distribution of species recorded per environment.

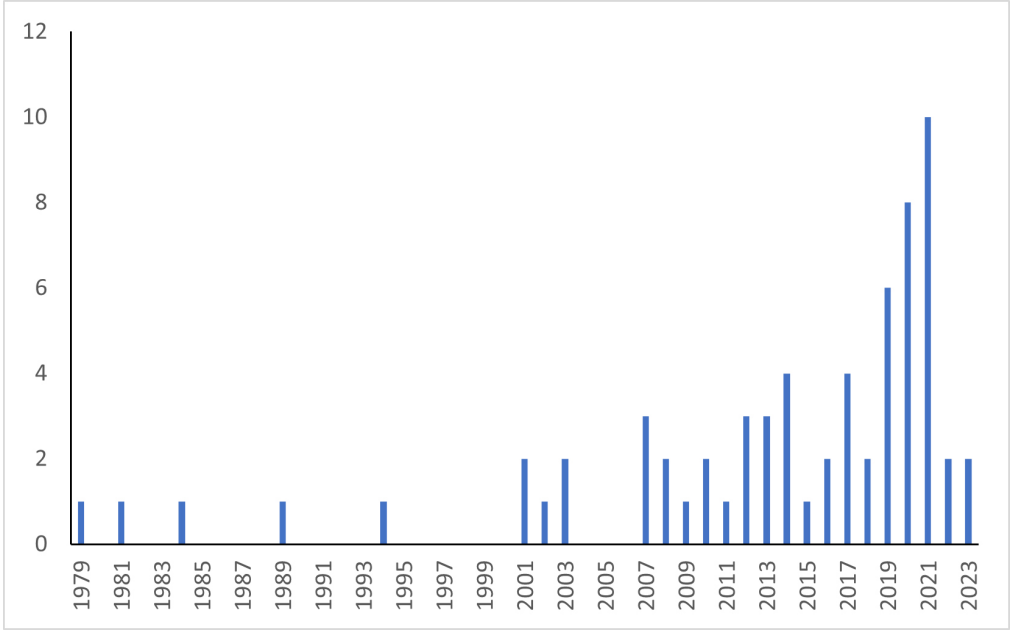

Fig. 3. Temporal distribution of studies involving small mammals in urban environments.

consultation: *Thrichomys laurentius* (corrected from *T. apereoides*), *Guerlinguetus brasiliensis* (which included *G. aestuans*, *Sciurus aestuans*, *G. alphonsei*, *G. ingrami*, and *Sciureus ingrami*), *Philander opossum* (corrected from *P. frenatus*), *Oligoryzomys matogrossae* (corrected from *O. fornesi*), *Metachirus myosurus* (corrected from *M. nudicaudatus*), and *Proechimys goeldii* (corrected from textitP. *guyanensis*). Records

Table 2

Taxa and studies recovered by the systematic review, distributed by Brazilian federative unit (state).

State	N. Taxa	N. Studies
AL	2	2
AM	3	4
BA	5	2
ES	1	1
MA	3	2
MG	18	15
MS	2	6
PA	8	3
PE	12	2
PI	2	1
PR	4	6
RJ	10	6
RS	2	3
SP	16	15

of *Didelphis marsupialis* in Bahia and São Paulo are potentially misdiagnosis for *D. aurita* or *D. albiventris*.

The record for *Caluromys* sp. was located within the distribution of *C. lanatus* and *C. philander*. *Cryptonanus* sp. was in the range of *C. agricolai*. The record for *Didelphis* sp. was in the range of *D. albiventris*. *Metachirus* sp. was in the range of *M. aritanai*, *myosurus*, and *nudicaudatus*. *Micoreus* sp. was in the range of *M. demerarae*. The record for *Trinomys* sp. was in the range of *T. albispinus*, *mirapitanga*, *setosus*, and *yonenagae*. *Akodon* spp. were in the range of *A. cursor*, *montensis*, *mystax*, and *paranaensis*. *Calomys* sp. was in the range of *C. cerqueirai*, *expulsus*, *mattevii*, and *tener*. *Cerradomys* sp. was in the range of *C. marinhus*, *scotti*, *subflavus*, and *vivoi*. *Euryoryzomys* sp. was in the range of *E. lamia* and *russatus*. *Oecomys* sp. was in the range of *O. catherinae*.

DISCUSSION

The field of urban biodiversity has only recently gained momentum in Brazil (Sartori et al. 2023), with studies focusing on compiling and understanding the patterns and processes that determine the composition and distribution of biotic communities in anthropic landscapes (Oprea et al. 2009; Nunes et al. 2017; Bernard et al. 2022). Our study highlights that, despite the growing *corpus* of publications, information on small mammals in urban settings is still spatially clustered and severely limited. Nonetheless, our results indicate that Brazilian urban areas are habitat to 23.5 % of marsupial and 6.3 % of rodent species in the country (excluding subspecies and identifications to the level of genus) (Abreu et al. 2022).

Despite listing more than half (14/27) of the states that form the Brazilian territory (**Fig**. 3), the distribution of studies -with disproportionate representation of states of the southeastern region, in particular Rio de Janeiro and São Paulo- was similar to what was observed by other systematic reviews on urban ecology (Sartori et al. 2023) and studies on other urban mammal taxa (Nunes et al. 2017). This phenomenon was expected given the concentration of research institutions, resources, and researchers in the region (including two of the most important natural history museums of Brazil, the Museum of Zoology of Universidade de São Paulo (MZUSP) and the Museu Nacional of the Federal University of Rio de Janeiro [MN-UFRJ]). This pattern also corresponds to the area with the largest urban centers of Brazil (the cities of São Paulo and Rio de Janeiro), the presence of large urban forest reserves, and the areas that presented the higher proportion of studies. Consequently, three out of the four most species-rich states are from the region.

As observed by Sartori et al. (2023), there is a paucity of studies on mammal fauna, in particular inventories and surveys, a pattern observed in our results (one inventory study). This highlights the importance of other types of studies as sources of information on diversity, given that studies on zoonosis and pathogens were both the numeric majority of the studies but also contributed with more than half of the rodent species and over 70 % of the marsupial species recorded. It is important, however, to be cautious when performing any sort of estimations (e.g., estimation of abundance) based on such literature records, as instances of using the same sample of individuals to produce several studies (salami science, e.g., Bezerra-Santos et al. (2020a,b,c,d)), or inconclusive/lacking information on capture effort and associated data were common issues detected in these studies. Zoonosis studies also inflated the representation of certain taxa in our studies, given that single-species studies could either be targeting a species given their ubiquity in the area, but also given their status as the specific local host for the pathogen(s) of interest. Such was the case of *Didelphis albiventris* and *Didelphis aurita*, which presented the highest frequency of single-species studies evaluating pathogen/parasite positivity.

Our findings highlight the importance of vegetation remnants to the maintenance of biodiversity in urban landscapes. Forest remnants (in the form

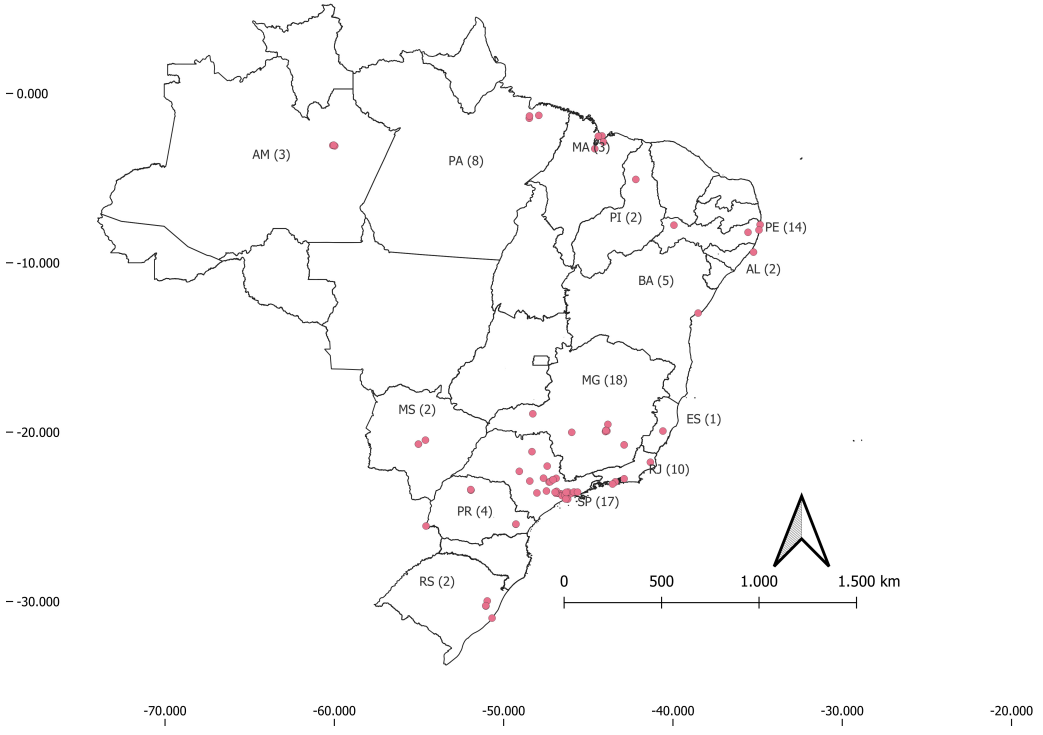

Fig. 4. Map of the sites where the studies retrieved were conducted. In parenthesis, the number of species recorded in each state. The number of dots in the map is not equivalent to the number of studies, as several studies were conducted at the same site. In studies in which no coordinates were presented or only the name of the municipality was cited, a random point within the limits of the municipality was picked. Coordinates in degrees decimal and projected in WGS 84. Map generated in QGIS.

of urban parks and urban forest reserves) were responsible for the majority of taxa recorded, with over half of the species being exclusive to forest fragments. While it is known that the intensity of urbanization, in regards to the composition of landscape features and land change intensity, has direct effects on species richness and abundance (Villasenor et al. 2014; Soultan et al. 2021), we believe that the differences in species richness observed are due to the presence of studies in large forest patches (e.g., Fontes do Ipiranga State Park, the largest urban Atlantic Forest remnant in Brazil with over 524 ha (Monticelli et al. 2021), Pedra Branca State Park, and Campus FIOCRUZ Mata Atlântica, the largest urban park in Brazil, covering over 12,492 ha). Forest remnants in university campi were also important sites for study (e.g., Cáceres & Moura (2003); Almeida et al. (2008)).

While our study provides valuable insights, it is essential to acknowledge a few limitations that might affect our findings. Primarily, it is likely that our results underestimate species richness and distribution given that studies focused on diversity were scarce in the observed studies, and several studies were focused on a single taxon, with the sampling techniques entirely dominated by a single method, live-trapping, which has limitations on species detectability (Gu & Swihart 2004). Inferences on the patterns of diversity based on the data retrieved in this study must include controls for publication and sampling bias, given that the more species-rich regions in our results are also the regions with a higher concentration of studies. Part of the studies included in the review presented limited taxonomic refinement, with several taxa identified to the level of genus. This could both inflate the taxonomic diversity observed (the genus-level taxa could represent species that were listed, creating duplicates) or mask true diversity (one or more studies with genus-level identifications could be representing different congeneric species as a single taxon in our list). The taxonomical issue is also important to be observed, as several taxa had to

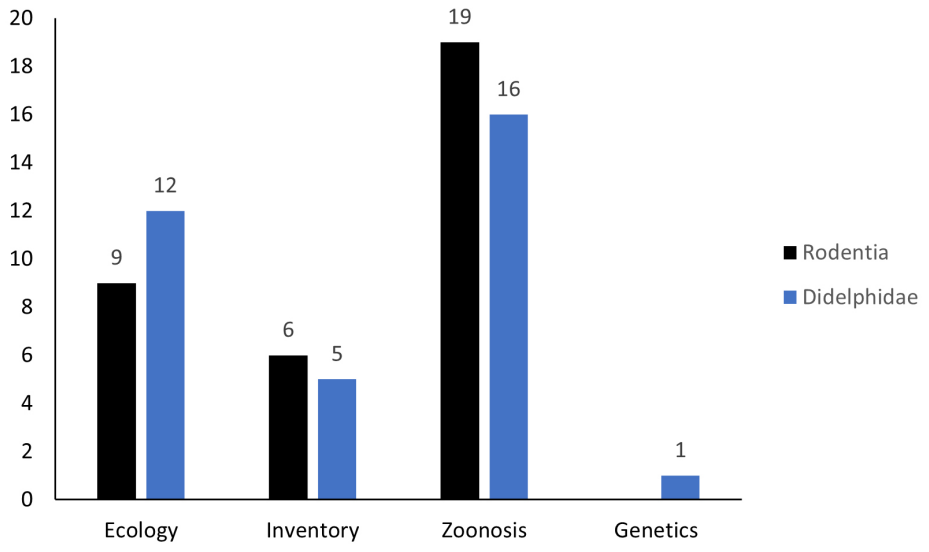

Fig. 5. Distribution of species records per type of study.

be reassessed and reidentified due to either changes in taxonomy (e.g., *Philander opossum*) or potential misdiagnosis (e.g.: *Thrichomys marsupialis* in São Paulo, potentially a misdiagnosis of *D. aurita* or *D. albiventris*), with taxonomical uncertainty potentially also becoming a factor that inflates the perceived diversity (as is the case with *Guerlinguetus brasiliensis*, identified as five distinct taxa in our review results). Finally, our study considered only peer-reviewed studies and could be ignoring reliable information from grey literature (such as technical reports from environmental authorities), thus underestimating the real diversity of urban small mammals.

CONCLUSIONS

Our findings contribute to the growing body of knowledge on urban biodiversity in Brazil, while emphasizing the need for more inclusive and geographically diverse research efforts to provide a holistic understanding of terrestrial small mammal diversity in (sub)urban environments across Brazil. Such understanding will guide future research, such as control and/or conservation strategies as may be needed.

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AUTHOR CONTRIBUTIONS

CGZ: construction of the search strings, triage of the data, data analysis, and manuscript writing. AMA: triage of the data, data analysis, production of visual elements, manuscript writing, and proofing.

CONFLICT OF INTEREST

The authors disclose no conflict of interest.

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ONLINE SUPPLEMENTARY MATERIAL

Table S1 - List of small mammal species registered for urban environments in Brazil. Each entry includes the states (and localities) of the records, sampling method, and type of study that generated the record.